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ELECTROENCEPHALOGRAM IN AUDITORY AND

VISUAL REACTION TIME TASKS

H. Jokeit

R. Goertzl

E. Kuchleri

S. Makeig

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EVENT-RELATED CHANGES IN THE 40 Hz ELECTROENCEPHALOGRAM IN AUDITORY AND VISUAL REACTION TIME TASKS

Hennric Jokeit[1], Ralf Goertz[2], Erika Küchler[2], and Scott Makeig[3]

[1]Institute for Medical Psychology, University of Munich, Germany

[2]Department of Psychology, Humboldt-University, Berlin, Germany

[3]Naval Health Research Center, San Diego, USA

1. INTRODUCTION

Mean motor response times (MRT) to expected stimuli can differ considerably between subjects even when experimental conditions are stable. It is well known that central rather than peripheral processes are mainly responsible for these differences (Glickstein, 1972; Luce, 1986). However, questions remain open whether and which measures of neuroelectrical brain activity can reveal significant aspects of the underlying sensorimotor processes. A number of studies using event-related brain potentials have yielded only small or insignificant correlations between electrophysiological measures and motor reaction times (Kutas et al., 1977; Goodin et al., 1990; Ortiz et al., 1993).

However, averaged evoked responses reveal only one aspect of event-related brain dynamics (Makeig, 1993). An important distinction can be made between evoked EEG activity, consisting of potential shifts which are both time- and phase-locked to experimental events and which are captured in ERPs, and induced EEG activity, also including oscillations time-locked but not necessarily phase-locked to experimental events (Eckhorn et al., 1988). Induced activity which is not phase-locked to experimental events does not appear in averaged evoked responses, but its mean tendencies can be measured by averaging event-related spectra.

It has been suggested that oscillatory brain activity in the gamma band (roughly 25-90 Hz) is intimately involved in elementary sensorimotor and cognitive processing (Singer, 1993). Electroencephalographic (EEG) studies have reported spontaneous cortical activity in the 40 Hz range during periods of increased alertness and vigilance (Boyer et al., 1987; Steriade et al., 1991), during accurate performance of a conditioned response (Freeman and Dijk, 1987), and during periods of focused arousal during cognitive task performance (Sheer, 1989) including reaction time tasks (Krieger and Dillbeck, 1987). Suppression of 40 Hz activity has been noted during central anaesthesia (Madler and Pöppel, 1987) and delta sleep (Llinas and Ribary, 1993). While stable gamma band features have been identified in averaged event-related potentials (ERPs) time- and phase-locked to auditory stimuli (Basar et al., 1976; Galambos et al., 1981; Makeig, 1990; Pantev et al., 1991), visual and olfactory studies in animals have found stimulus-induced cortical gamma band activity that typically takes the form of brief, irregular bursts (Freeman and Skarda, 1985; Basar-Eroglu and Basar, 1991; Singer, 1993) which follow, but are not reliably phase-locked to stimulus onsets. Therefore, it is reasonable to wonder whether the temporal dynamics of 40 Hz activity in the human EEG are related to particular sensorimotor tasks and individual different performances.

The experiments reported here were conducted to examine event-related changes in spectral power in the 40 Hz range induced by a simple auditory and a visual priming reaction time task. More detailed analyses of both experiments are being documented (Jokeit and Makeig, in press; Gertz, Jokeit, and Kuchler, in preparation).

2. A SIMPLE AUDITORY REACTION TIME TASK

2.1. *Methods*

In the first experiment, 23 right-handed adults (ages 20-53) were tested in two conditions. First, 110 clicks (2 ms width, 75 dB SPL) were presented binaurally at random inter-stimulus intervals (ISIs) of 3 to 7 s. Subjects were then asked to react as quickly as possible to a second set of 275 clicks (with the same intensity and ISI distribution) by pressing a response button with the index finger of their right hand. EEG was collected from a scalp electrode located at the vertex (Cz) referred to linked mastoids.

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EEG epochs of 640 ms beginning 128 ms prior to each click were recorded with a sampling rate of 2000 Hz using a 12 bit A/D converter with an analog high pass filter cutoff of 0.67 Hz and a 50 Hz line frequency notch filter. To exclude large eye movements and muscle activity, epochs in which potential anywhere exceeded +/-70 μV were eliminated from the analysis. Reaction time (RT) was recorded separately with a temporal resolution of 1 ms. Trials with RTs shorter than 100 ms or longer than 600 ms were also eliminated. On average, 80% of the trials were retained for analysis. Averaged evoked gamma band responses (GBRs) were computed by applying a 20 to 60 Hz bandpass filter to the epochs before averaging. All filtering used symmetric Butterworth filters with 24 dB/octave slopes.

To compute 40 Hz band event-related spectra (ERS), each response epoch was first band pass filtered from 20-60 Hz. The epochs were then divided into 68 overlapping 24-point (96 ms) time windows with a shift interval of 8 ms. After tapering using a Gaussian window function, and zero-padding to 64 points, each window was converted to spectral power using an FFT. Since gamma band power was interrupted by the 50 Hz notch filter used in the recording, the range 35 to 43 Hz was chosen for analysis. Power in this range was integrated for each time point using a Hamming window function. The 40 Hz ERS transform of each epoch thus consisted of 68 power estimates at 8 ms intervals. Statistical significance of response differences in the measures was tested by repeated measures analysis of variance (RM-ANOVA), by Bonferroni-corrected t-tests for dependent samples, and by t-tests for independent samples. Threshold of significance was considered to be $p<0.01$.

2.2. Results

Grand mean GBRs for the speeded response (RT) and the passive listening (noRT) condition (Fig. 1A) each contain above-baseline activity during approximately the first 100 ms after click presentation. As shown in Fig. 1A the GBR did not vary as a function of task. Although the GBR was unaffected by task, there were task differences in the 40 Hz ERS (Fig. 1B,C). In the RT condition the subjects had significantly more 40 Hz power just prior to the stimulus than in the noRT condition. Following the stimulus, both ERS curves reach their maximum during the first 100 ms after stimulus onset, paralleling the activity visible in the GBR (Fig. 1A).

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To reveal possible dependencies between the temporal dynamics of 40 Hz activity and mean motor response time, Pearson correlation coefficients between each data point of each subject's mean ERS curve and their mean reaction time were computed. Fig. 1D (bold trace) shows that the mean 40 Hz ERS power is significantly correlated with the mean response time at several latencies. Moreover, the existence of a temporal chain of significant positive and negative correlation coefficients indicates high temporal dependencies within the mean ERS curve. In contrast, the correlation function of the ERS curves of the noRT condition re reaction times in the RT condition (light trace) did not reveal any significant correlations.

To attempt to better characterize the correlations between the ERS curve of the RT condition and the mean reaction times, the individual mean ERS difference curves (RT-noRT) were submitted to a Q-factor analysis on subjects with Varimax rotation. With one exception, all subjects loaded positively on the first factor (F1), which explained 46% of the total variance. The second factor (F2), explaining 25% of variance, clearly split the other 22 subjects into two groups by its (+/-) sign of loading. Plotting the 22 individual F2 loadings against individual mean RTs (Fig. 1E), two subject subgroups emerge clearly. The ten subjects whose mean RTs were less than 195 ms load in the opposite direction to the twelve remaining subjects, whose mean RTs were longer than 195 ms. In fact, the factor analysis separated subjects by mean RT: no subject in the slow responder group had a lower mean RT than any of the fast responder group, and accordingly the mean RT of the 10 fast responders (176+/-44 ms) was significantly faster than that of the 12 slow responders (244+/-78 ms). The resulting decomposition of the sample RT distribution into two significantly different sub-distributions is shown in Fig. 1F.

Grand mean GBRs, and ERS responses were then calculated for the two subject groups. There were no significant group differences in the GBRs. Figures 2A and 2B show mean 40 Hz ERS responses for the fast and slow responders in the RT condition. While mean ERS power did not differ significantly between the two groups, there was a significant group difference in its temporal dynamics, and the interaction of group and dynamics was also significant. .

Group comparison of difference waves between ERS responses in RT and noRT conditions (Fig. 2C,D) shows the effects of task and group affiliation on 40 Hz ERS dynamics. The dotted lines in Figs. 2C and 2D give limits of significant difference (p=0.01). The most prominent component in the difference wave for the fast responders is a relative peak at 200 ms, followed by a

second peak at about 400 ms which also reaches significance. In contrast, the (RT-noRT) ERS difference for the slow responders (Fig. 2D) contains no peaks following stimulus presentation. Instead, in the RT condition these subjects had significantly more 40 Hz power just prior to the stimulus than in the noRT condition.

To test the consistency of the group differences, and to assess effects of varying RTs within groups, response epochs in the RT condition were separated into relatively fast-RT and slow-RT subsets, depending on whether RT was longer or shorter than the subject median. The dotted lines in Figs. 2A and 2B show the ERS averages for these fast- and slow-RT epochs from the two groups. The 40 Hz ERS differences between the two groups are clearly maintained, even between the relatively slow-RT epochs of the fast responders (RT=201+/-48 ms), and the relatively fast-RT epochs of slow responders (RT=202+/-36 ms), data subsets in which mean RT did not differ significantly. Statistical comparison confirmed that there were no significant within-group effects of RT subset on ERS dynamics. Finally, the two ERS data subsets were again correlated with the mean reaction time. Neither the ERS curves of the fast nor of the slow responders elicited further reaction time dependencies, revealing that the observed correlation of the whole sample was based on the different ERS patterns of the slow and fast responders.

3. A VISUAL PRIMING REACTION TIME TASK

3.1. *Methods*

In the second experiment, involving a visual priming paradigm, 16 right-handed adults (ages 19-35) were asked to react as quickly as possible to three different sets of visual stimuli: digits, vowels, and consonants. Each set was restricted to five stimuli and was assigned to a separate response button and response finger. The stimuli were displayed in the center of a computer screen. One second prior to the target, a priming stimulus was presented at the same location. The information content of the priming stimulus, and the assignment of the response button was varied between blocks. In the Information (INFO) condition, the priming stimulus was either a "b", indicating a letter, or a "z", indicating that a digit was to follow. Digits were used as distractor items and were removed from analysis. In the cueing (CUE) condition, an asterisk "*" was presented in place of the priming stimulus. In two of the four presented blocks priming information was given. A block consisted of 400 items, so each subject had to respond to 1,600 items. Interstimulus

intervals varied between 3 and 7 seconds.

The EEG was collected from Cz referred to linked mastoids. The recording epoch began 250 ms prior to the onset of the priming stimulus and lasted 1750 ms, i.e. to 500 ms after the onset of the target stimulus. A 50 Hz notch filter and an analogue band pass filter with cut-offs at 3 and 70 Hz were used during data collection. The data were sampled with a 12 bit A/D converter at a rate of 1000 Hz. EOG was also collected, and was used to reject epochs containing artifacts as in the first experiment.

Each recorded epoch was digitally band pass filtered using a symmetric Butterworth filter (12 dB/octave) with cut-offs at 20 and 60 Hz. An analyzing window of 100 ms was shifted across the whole epoch in steps of 10 ms. Data within the overlapping windows were Fourier transformed to obtain 40 Hz amplitude. Thus an ERS epoch consisted of 166 data points. The estimates for each window were separately averaged across trials for both conditions. To obtain baseline-independent dynamics, the amplitudes were divided by the mean amplitude of the prestimulus interval, and the decimal logarithm of this quotient was multiplied by 20. The difference between the two conditions was also computed. This difference can be regarded as the 40 Hz activity due to processing of information given by the priming stimulus. A repeated-measures ANOVA for both conditions was calculated using information as a factor. A separate repeated-measures ANOVA was computed for the difference between conditions.

Averaged evoked gamma band responses (GBR) were separately computed for both conditions using a 32 to 48 Hz bandpass filter with 24 dB/octave slopes. Response times were recorded with a temporal resolution of 1 ms. The data of the correct responses were statistically screened by applying the two-tailed Thompson rule to remove extreme values. To estimate how well a subject used the given information, the effect size was computed as the difference between the mean response times under both conditions, divided by the weighted and pooled standard deviation of the response times.

To investigate the influence of the 40 Hz event-related spectrum on effect size, we computed a running (Pearson) correlation between the 40 Hz ERS difference curves (INFO minus CUE conditions) beginning 10 ms after priming stimulus onset and the reaction time effect size. Threshold of significance was considered to be $p < 0.01$.

3.2. Results

Due to data loss, data from only 15 persons could be analyzed. For these subjects, on average 80 percent of all trials were judged free of artifacts. As expected, subjects responded significantly more quickly under the information condition: Mean RT in the INFO condition was 674 ms and in the CUE condition, 723 ms. All but three subjects seemed to take advantage of the given information, i.e. their responses were quicker in the INFO condition.

A recognizable averaged evoked gamma band response (GBR) was found for 8 of the 15 subjects. Figure 3A illustrates the high inter-individual variability of the GBR in four subjects. Subjects s3 and s4 show clear above baseline activity after prime onset. The onset latency of visual GBR activity was longer than gamma band responses to auditory stimuli, beginning about 100 ms after priming stimulus onset, whereas its amplitude was smaller than corresponding auditory response. The average responses of the other two subjects (s1 and s2) appear to contain no above-baseline phase-coherent gamma band response activity.

The 40 Hz event-related spectrum showed a greater variability between subjects than in the auditory task, but for most subjects, an increase in 40 Hz amplitude immediately after priming stimulus onset was observed, followed by a suppression after about 250 ms (Fig. 3B). This was followed by a second peak at about 600 ms. The trend-reduced ERS grand average in Fig. 3B discloses a similar biphasic structure after the onset of the target stimulus. The first increase seems to be related to the occurrence of the GBR. Repeated measures ANOVAs for the both conditions, however, revealed significant temporal changes in the 40 Hz ERS, but neither the information factor, nor the interaction between time and information were significant. A repeated measures ANOVA for individual ERS difference between INFO and CUE conditions, however, showed a significant effect of time. Figure 3C gives the correlation between the ERS difference between the two information conditions, and the information effect on mean response time. All correlations were positive, but only the values in the interval 170 to 250 ms exceeded significance threshold. In other words, subjects whose mean reaction time became shorter when priming information was presented also had increased EEG amplitude at 40 Hz in the interval 170-250 ms following the priming stimulus.

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4. DISCUSSION

The task and response mode-dependent temporal patterns of gamma band EEG activity reported here appear to capture significant dynamics of cerebral activity in the 40 Hz range involved in task-related cognitive and sensorimotor processing, and demonstrate that these dynamic patterns can depend on subject, task, modality and level of performance. The results of both experiments indicate that dynamics of 40 Hz activity are intimately related to early stages of sensorimotor and cognitive processing.

The experiment on simple auditory reaction times reveals stable individual and group differences in stimulus/response brain processing associated with distinctive temporal patterns of stimulus-induced changes in the 40 Hz EEG. Although there were no task-related differences in time- and phase-locked stimulus-evoked gamma band activity between passive listening and speeded response tasks, reliable time-locked and task-dependent patterns of changes in ERS power near 40 Hz were induced by auditory stimuli. Moreover, two stable patterns of event-related dynamics of 40 Hz EEG activity occur in separate subsets of subjects, one with relatively fast mean response times, and another consisting of subjects who, on average, respond more slowly.

Figs. 2A-D show convincingly that similar mean spectral EEG power may result from quite different event-related patterns of spectral activity, and that at least two different 40 Hz activity patterns (Fig. 2A,B) accompany speeded reactions in behaviorally distinct subject subgroups (Fig. 1E). Although there was no overall difference in 40 Hz power between relatively fast and slow responders, the dynamics of 40 Hz activity preceding and following the stimuli were qualitatively different for the two groups.

In differences between speeded response and passive listening conditions, slow responders produced relatively greater power near 40 Hz only prior to the auditory stimulus; following it, 40 Hz power did not differ between the two task conditions (Fig. 2D). In contrast, the fast responders' ERS patterns contained equal amounts of 40 Hz power prior to the stimuli in both tasks, but in the speeded response condition they displayed phasic relative increases in 40 Hz power peaking near 200 and 400 ms after stimulus presentation (Fig. 2C). Since above-baseline 40 Hz activity in the evoked response lasts less than 200 ms (Figs. 1A), later ERS activity must reflect

spectral activity regularly induced following stimulus presentations but not reliably phase locked to them. The independence of the two groups' response patterns from reaction time *per se* is shown by the high consistency of the mean ERS responses for the fast versus slow-RT comparisons for each subject group (Fig. 2A,B dotted lines). The apparent dissociation of individual RTs and ERS dynamics, as revealed by the fast- versus slow-RT comparisons, implies that this differentiating late 40 Hz activity is also not time locked to the execution of the response. Therefore, it is reasonable to conclude that stable subject differences in neurocognitive processing can occur even in a simple speeded response task resulting in equivalent levels of performance.

The significantly larger pre-stimulus 40 Hz activity in the slow responders might reflect a kind of heightened anticipation or focused preparation to facilitate controlled sensorimotor processing (Sheer, 1989; Crick and Koch, 1990). One might speculate that an increased state of anticipation of the stimulus in slow responders (Fig. 2C), might in turn require more fully elaborated and time-consuming stimulus processing, accompanied by a more distinct perception of the stimulus, prior to initiation of a motor response. The existence of qualitatively different response modes, as opposed to graded individual differences in response speed, might also relate to the theoretical dichotomy between automatic and controlled processing which has been proposed to categorize qualitative differences in performance in many task and training conditions (Schneider and Shiffrin, 1977; Norman and Shallice, 1986).

The second experiment, employing a visual priming task, showed that a time- and phase-locked gamma band response to visual stimuli is also observable in some subjects. However, the latency of the GBR, as well as that of the first peak in the ERS curve, is about 100 ms later than for auditory stimuli. Possibly, longer transduction and processing times in visual compared with auditory pathways may lead to a much higher inter-trial and inter-individual phase variability in the GBR, resulting in noisy and small GBR amplitudes. This view is supported by the fact that subjects without a noteworthy GBR in some cases had a prominent increase in event-related 40 Hz activity during the same time range. The ERS transforms show also phasic increases following the target stimuli (Fig. 3B) although a grand mean GBR cannot be detected.

The most prominent feature of the highly correlated ERSs in both conditions is the decrease of the 40 Hz amplitude at 250 ms following the first peak after prime presentation. A slow negative-going shift was observed in the averaged event-related slow potential. However, the onset

of this contingent negative variation (CNV) occurred about 600 ms after prime onset. In the auditory experiment, the average ERS of the slow responders of the RT condition (Fig. 2B) also showed an apparent post-stimulus suppression of 40 Hz activity, though on a shorter time scale. However, this apparent suppression was actually due to an increase in 40 Hz prestimulus power, as shown by comparison with the reference noRT condition. Therefore, the significant prestimulus difference between RT and noRT conditions and the absence of any difference following the stimulus in the grand and slow responders average 40 Hz ERS may be distinguished from event-related desynchronisations of ongoing brain activity in alpha and beta bands of the EEG (Pfurtscheller, 1977; Kaufman et al., 1990). It is reasonable to speculate that in the visual priming task, expectation of a priming stimulus is associated with an above-baseline increase in 40 Hz activity prior to the priming stimulus.

The 40 Hz ERS in both task conditions are highly correlated (r=0.95). Therefore, we assume that the observed temporal pattern of 40 Hz activity is primarily related to a task-defined processing mode. This could also explain why a repeated measures ANOVA on ERS data failed to reveal a significant effect of the priming information, or an interaction of temporal dynamics and information. In addition, the large inter-individual variability in 40 Hz dynamics, paralleling similarly large between-subject differences in performance, has to be taken into account. However, individual differences between the INFO and CUE conditions show still a significant effect of time, indicating the existence of changes in these patterns due to the processing of response relevant priming or alerting information or with preparation for response selection and processing.

The fact that correlations between the ERS difference wave and reaction time effect sizes were positive means that subjects whose mean reaction time became shorter when priming information was presented also tended to have increased EEG amplitude at 40 Hz during the epoch. In other words, the presence of high 40 Hz amplitudes is associated with good performance. Interestingly, the interval from 170-250 ms after priming stimulus onset appears to be the most important time for utilizing priming information as indicated by significant correlation coefficients. It can be assumed that by 170 ms encoding processes have already been terminated, and processes of decision making as well as response preparation would have started. In the auditory reaction time experiment, we found that the observed correlations between 40 Hz activity and reaction times were based primarily on stable group differences between slow and fast responders. The absence of significant correlations between 40 Hz ERS and response times within the fast and slow subgroups in the

auditory experiment, however, does not contradict the occurrence of significant correlations in the visual priming task, since in the visual condition, the response time effect size (the difference between the two conditions) and not the raw response times, as in the auditory experiment, were found to yield significant correlations.

In summary, it appears that time-frequency averaging methods applied to 40 Hz EEG data recorded during auditory and visual experiments of different degrees of complexity may be useful for studying brain processes involved in performance of sensorimotor and cognitive tasks. From the results of both experiments we suggest that the dynamics of 40 Hz activity are related to stimulus processing and response preparation. In the auditory reaction time task, only relatively slow responders had increased 40 Hz activity prior to the stimulus onset, which we interpret as meaning that these subjects required more fully elaborated and time-consuming stimulus processing, accompanied by a more distinct perception of the stimulus, before initiation of a motor response. Such a response mode, however, seems to be more appropriate for more complex tasks like that presented in the visual priming paradigm. In that experiment our results suggest that an exhaustive stimulus processing and focused response preparation, accompanied by increase in circa 40 Hz activity leads to faster responses.

ACKNOWLEDGEMENTS

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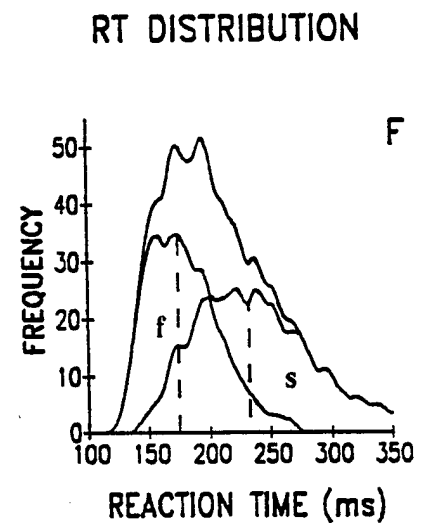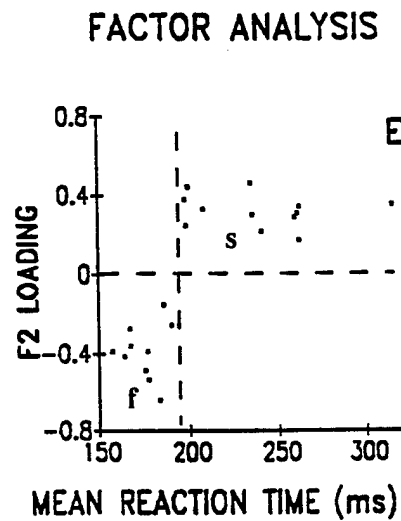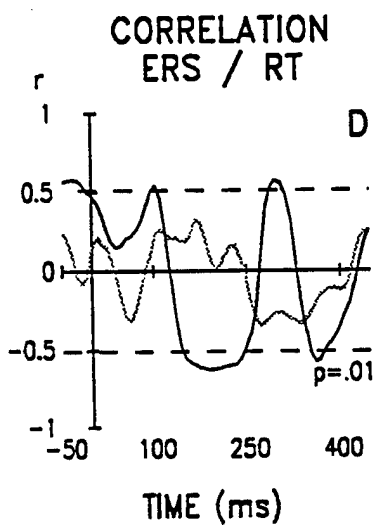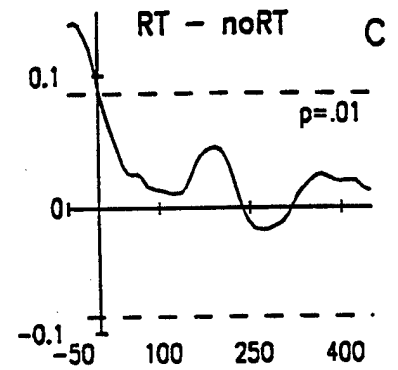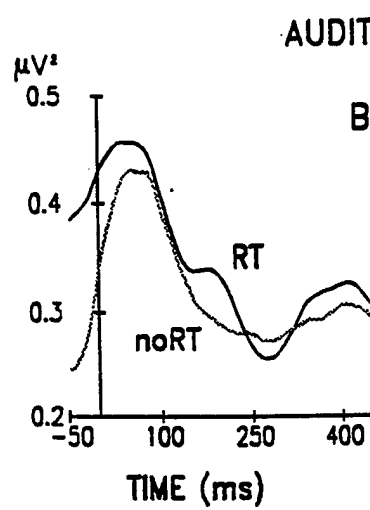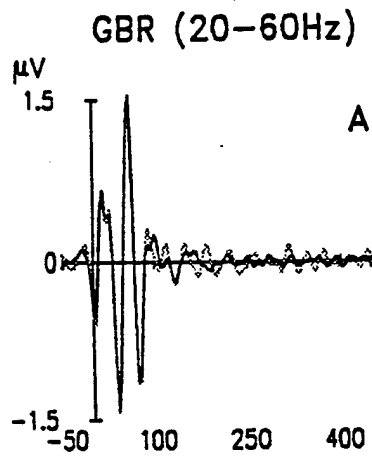
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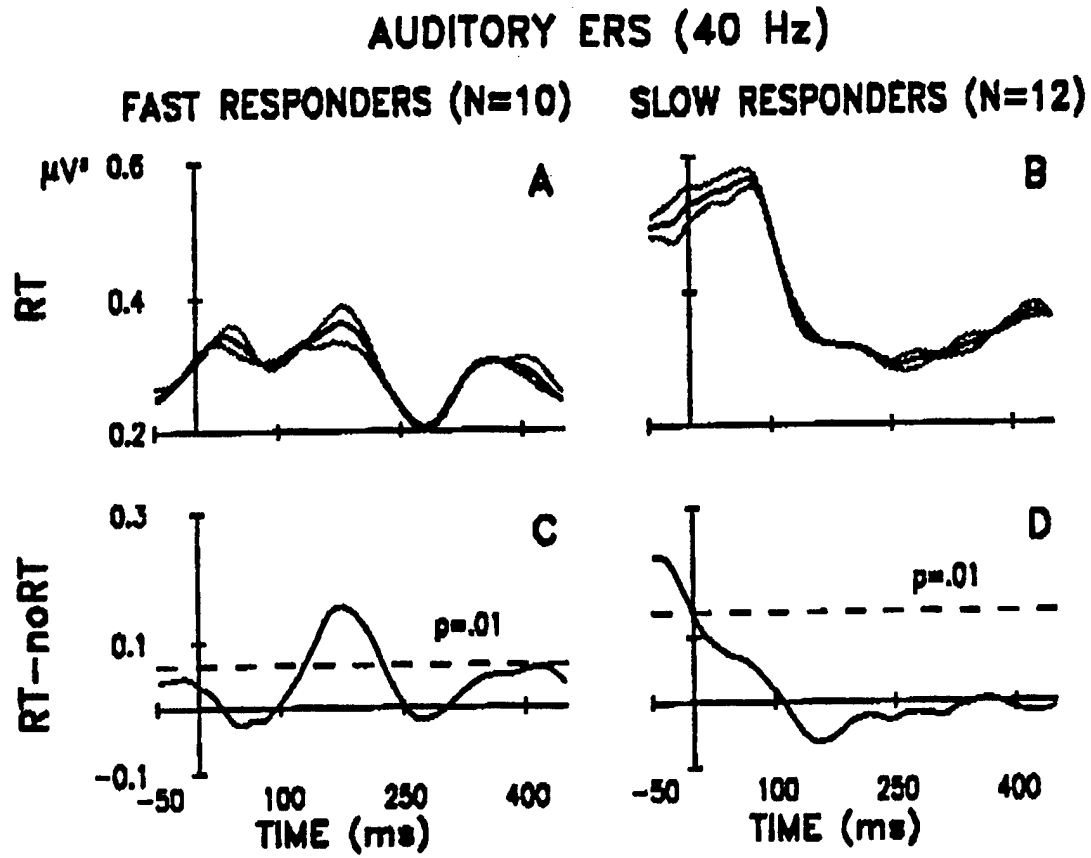
FIGURE LEGENDS

Fig. 1 : Responses to clicks in passive listening (noRT) and speeded motor response (RT) task conditions. Grand means of responses from 23 adult subjects (site Cz referred to linked mastoids). (A) Grand mean gamma band responses (GBRs), bandpass filtered between 20 and 60 Hz. Abscissa is time re the onset of the click. The ordinate is potential in µV. Note the above baseline activity after stimulus onset. (B) Grand mean event-related spectra (ERS) for two task conditions: speeded motor responses (RT) and passive listening (noRT). Each trace plots mean time-varying power near 40 Hz. Abscissa: time re stimulus onset. Ordinate: power in µV2. (C) ERS difference curve between both task conditions which differs significantly only prior to the click onset. (D) Pearson correlation coefficients between ERS power at each time point in the RT condition and mean response times. The correlation for the noRT condition (dotted) is also shown. Abscissa: time re stimulus onset. Ordinate: Pearson correlation coefficient r. Dotted line shows limits of significant correlations (p<.01). (E) Factor analysis on subjects (Q-Factor Analysis) performed on a Pearson correlation matrix on task differences between individual event-related spectra (ERS) at 40 Hz. Output submitted to Varimax rotation. Scatter plot of the second factor F2 against individual mean reaction time (RT). Abscissa: mean RT in ms. Ordinate: the subject's loading on F2. Note that F2 separates subjects by mean RT: no subject in the 'slow' group had a lower mean RT than any of the 'fast' group. (F) Reaction time distribution of 23 subjects and sub-distributions of the 10 fast ('f') and 12 slow ('s') responders respectively.
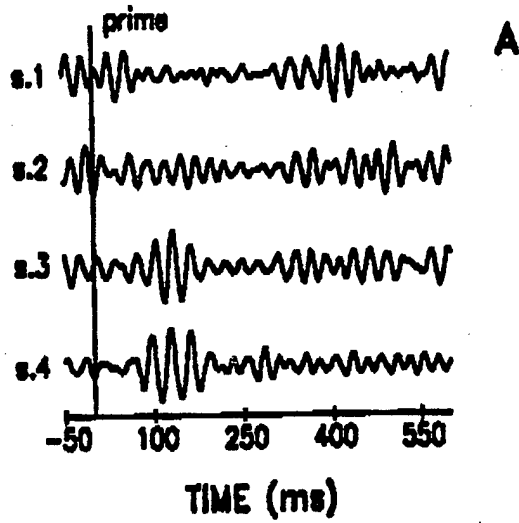
Fig. 2: Grand mean 40 Hz event-related spectra (ERS) for two subject subgroups: 10 fast responders and 12 slow responders from the original 23 subjects. Task conditions: speeded motor responses (RT) and passive listening (noRT). Each trace plots mean time-varying power at 40 Hz at site Cz (referred to linked mastoids). See text for details of group selection and spectral transform parameters. Abscissa: time re stimulus onset. Ordinate: power in µV2. (A) Mean ERS of 10 fast responders and (B) Mean ERS of 12 slow responders, both in the RT task condition. The dotted traces show the ERS averages for above- and below-RT median epochs from the fast and slow responders, respectively. The solid vertical lines represent grand mean RTs, and the dotted vertical lines, the means of above- and below-median RTs, respectively. (C) Difference wave between the RT and noRT task responses for the fast responders. (D) Difference wave for the slow responders. Dotted lines in C and D show limits of significant difference (p<.01).

Fig 3. Responses to visual stimuli in a priming reaction time task. Grand means of responses from 15 adult subjects (site Cz referred to linked mastoids). (A) Individual mean averaged gamma band responses (GBRs), bandpass filtered between 32 and 48 Hz. Abscissa is time re the onset of the priming stimulus. The ordinate is z-transformed potential (0+/-1). Note the above baseline activity after stimulus onset in subjects s3 and s4. (B) Grand mean event-related spectra (ERS) for two priming conditions: in which the priming stimulus gives information about the target (INFO condition), or simply cues the appearence of a target (CUE condition). Each trace plots mean time-varying power at 40 Hz. Abscissa: time re stimulus onset. Ordinate: amplitude in dB re prestimulus interval. The lower traces show the dynamics of the upper two traces after minimizing the linear trend by differentiation. Note the relative increases of 40 Hz power after prime and target onset, followed by secondary peaks. (C) Pearson correlation function between ERS difference between INFO and CUE conditions and reaction time effect (weighted difference in mean RT between the same conditions). The dotted line shows limits of significant correlation (p<.01). The uniformly positive correlations suggest that the presence of high 40 Hz amplitudes is associated with faster reaction times.

GBR (20–60Hz)

μV

1.5

A

0

-1.5
-50   100   250   400

AUDITORY ERS (40 Hz)

μV²

0.5

B

0.4

RT

0.3

noRT

0.2
-50   100   250   400

TIME (ms)

RT – noRT   C

0.1
- - - - - - - - - - - - - - - -
p=.01

0

-0.1
-50   100   250   400

CORRELATION ERS / RT

r

1

D

0.5 - - - - - - - - - - - - - - -

0

-0.5 - - - - - - - - - - - - - -
p=.01

-1
-50   100   250   400

TIME (ms)

FACTOR ANALYSIS

0.8

E

0.4
s

0
- - - - - - - - - - - - - - - -

-0.4

f

-0.8
150   200   250   300

MEAN REACTION TIME (ms)

RT DISTRIBUTION

F

50

40

30
f

20

10
s

0
100 150 200 250 300 350

REACTION TIME (ms)

AUDITORY ERS (40 Hz)

FAST RESPONDERS (N=10)   SLOW RESPONDERS (N=12)

VISUAL GBR (32-48 Hz)

A

prime

s.1

s.2

s.3

s.4

-50   100   250   400   550

TIME (ms)

VISUAL ERS (40 Hz)

B

dB 0.2

0

-0.2

-0.4   INFO

-0.6

CUEING

-0.8

prime   target

CORRELATION ERS/RT (effect)

C

r

p=.01

0.6

0.4

0.2

0

prime   target

-0.2
0   300   600   900   1200 1500

TIME (ms)

0.1

0

-0.1

-0.2

(trend reduced)

-0.3
-100 200   500   800   1100 1400

TIME (ms)
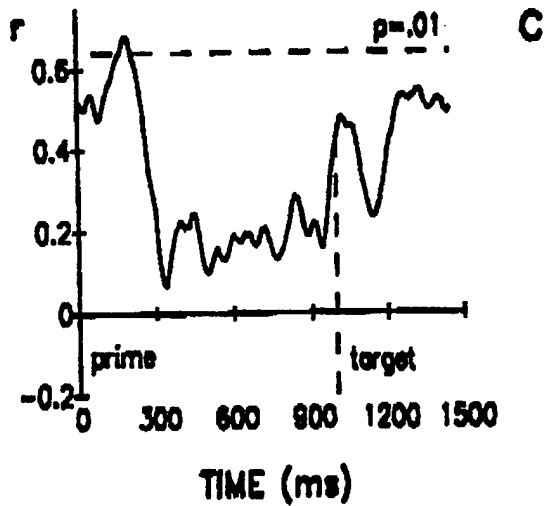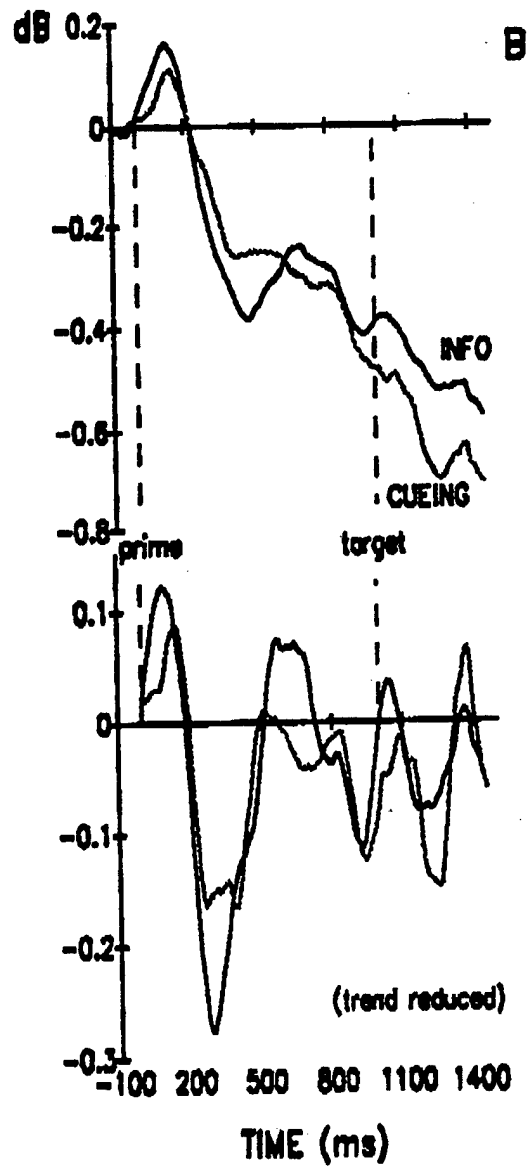
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H. Jokeit, R. Goertzl, E. Kuchleri, S. Makeig

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Health Research Center
P.O. Box 85122
San Diego, CA 92186-5122

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13. ABSTRACT *(Maximum 200 words)*

Mean motor response times (MRT) to expected stimuli can differ considerable between subjects even when experimental conditions are stable. It is well known that central rather than peripheral processes are mainly responsible for these differences. However, questions remain open whether and which measures of neuroelectrical brain activity can reveal significant aspects of the underlying sensorimotor processes. A number of studies using event-related brain potentials have yielded only small or insignificant correlations between electrophysiological measures and motor reaction times.

To compute 40Hz band event-related spectra (ERS), each response epoch was first band pass filtered from 20-60 Hz. The epochs were then divided into 68 overlappping 24-point (96ms) time windows with a shift interval of 8 ms. After tapering using a Gaussian window function, and zero-padding to 64 points, each window was converted to spectral power using an FFT. Since gamma band power was interrupted by the 50 Hz notch filter used in the recording, the range 35 to 43 Hz was chosen for analysis. Power in this range was integrated for each time point using a Hamming window function. The 40 Hz ERS transform of each epoch thus consisted of 68 power estimates at 8ms intervals. Statistical significance of response differences in the measures was tested by repeated measures analysis of variance (RM-ANOVA), by Bonferroni-corrected t-tests for dependent samples, and by t-tests for independent samples. Threshold of significance was considered to be $p<0.01$.

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